5G K-SimNet: Network Simulator for Evaluating End-to-end Performance of 5G Cellular Systems

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Abstract—We introduce the network simulator for evaluating end-to-end performance of 5G system, named as 5G K-SimNet. 5G K-SimNet provides the features of dual radio protocol, traffic management on multi-connectivity, and software-defined network/network function virtualization.

Index Terms—5G, Multi-connectivity, SDN, NFV, Network simulator

I. INTRODUCTION

Evolution to 5G is essential because of explosive mobile traffic and demand for high data rate service. Until 2017, 3GPP group had performed the first phase of standardization of the 5G mobile communication system, 5G Phase-1. The deployment methodology of 5G new radio (NR) and the need for network softwarization are discussed in [1]. [2] provides an overview of the multi-connectivity operation using LTE and NR radio access technologies. Software-defined network/network function virtualization (SDN/NFV) is discussed as a promising solution for network softwarization [3].

In this paper, we introduce 5G K-SimNet, the network simulator for evaluating end-to-end performance of 5G system (5GS). 5G K-SimNet is developed based on ns-3 [4] and has the features of dual radio protocol, traffic management on multi-connectivity, and SDN/NFV.

II. 5G K-SIMNET: MAIN COMPONENTS

Fig. 1 represents the simulator architecture of 5G K-SimNet. The 5G K-SimNet is being expanded from ns-3 and its SDN module [5]. 5G K-SimNet currently supports LTE-NR multi-connectivity and SDN/NFV modules for evaluating end-to-end performance. Multi-connectivity is one of the most important 5G features to deploy 5G NR with stable control-plane connectivity. SDN/NFV module is an essential function for the network slicing technology. The green-colored blocks of LTE-NR dual protocol stack, interfaces, SDN/NFV, and virtualization delay in Fig. 1 are implemented for supporting new 5G features. So far, the SDN/NFV module has been developed based on the existing 4G EPC network, but the 5G core entity will be developed and applied through continuous updating [6].

A. LTE-NR Dual Radio Protocol

LTE-NR dual radio model includes the LTE radio protocol stack and the 5G NR protocol stack. These entities reside entirely within a UE and an eNB/gNB. This model is based on multi-connectivity [2], providing the cooperating network architecture between 4G LTE and 5G NR in the transition period from 4G to 5G. Fig. 2 shows the block diagram of multi-connectivity for user plane in downlink case. A eNB is deployed as a control-plane anchor node (master node, shortly MN) and gNB is deployed for boosting the user throughput or balancing load between eNB and gNB (secondary node, shortly SN). The downlink traffic splits at the PDCP entity at eNB and routing to either the RLC entity at eNB or that at gNB. In order to enjoy the multi-connectivity, the traffic split function is deployed at MN. The traffic split entity is defined for all traffic individually. The PDCP TX entity, split layer, should perform the packet sequencing for the PDCP RX entity to re-order the split packets. The PDCP RX entity, aggregation layer, should perform the packet re-ordering to guarantee in-sequence deliver of the received packet to upper layer. We have
developed the dual radio protocol stack, the packet sequencing, packet re-ordering, and simple traffic split algorithm exploiting the LTE model, developed by LENA [7], and the mmWave radio model, developed by New York university (NYU) [8]. Using this model, we can evaluate the performance of the protocol for multi-connectivity. For example, the following features can be evaluated: traffic split/routing algorithm, RLC queue management scheme, MAC scheduling algorithm, and so on. These algorithms and schemes can be modified or developed by users. The simulation results are as follows: i) end-to-end performance, such as TCP/UDP throughput, round trip time (RTT), and congestion window size, ii) specific protocol performance, such as PDCP packet drop rate, RLC queue size/delay, PHY SINR values, and so forth.

B. SDN/NFV

It is expected that 5G Core (5GC) utilizes NFV and SDN techniques [3]. More specifically, in a 4G System, the EPC network functions are implemented on black boxes, however, in the 5GS, network functions become softwarization, not implemented on black box hardwares. Each network functions are installed and run on virtual machines (VMs) of NFV platforms, instead of black boxes. And these VMs can have connectivity with each other utilizing SDN technique, while monitoring and controlling network traffic among them. These changes make network operators be able to manage networks more easily and flexibly. For example, if a network function run on a VM becomes overloaded due to too high computational workload, a network operator can run another VM through an NFV platform. Then it can migrate some part of workloads from the original network function to newly booted one. However, by the NFV/SDN techniques, additional delays caused by provisioning and migrating VM could be added to end-to-end communication delay [9]. Our SDN/NFV components include the function which measures these side effects of introducing virtualization and SDN techniques to 5GC of 5GS.

Delay side effect means additional delays components compared to non-virtualized core networks. Additional delays depending on where network operators put VNFs (VNF topology) can be evaluated. For example, scaling delay can be caused by introducing NFV technique to 5G core network. With NFV, each of 5G core entity could be run on VMs, forming VNF. If the VNF has 8 CPUs but its workload exceed it, NFV platform auto-scales the VNF. In this case, the VNF is scaled-out, so two VNFs might be operated. This auto-scaling takes some delays, so user might experience temporally longer latency due to NFV technique.

Operation side effect means that with SDN, we can control network traffic flowing through core networks. Traffic rerouting or balancing operation can be evaluated. The simulation results are end-to-end performances including VM delay, network delay, and so on. User can engineer traffic which flow through SDN networks, and verify it with SDN switch throughput per port.

The simulator reflects such side effects by following simulation process of Fig. 3. First, users should set their own simulation topology and parameters related to SDN/NFV operation. Once they (user codes) are provided to the simulator, it runs in two ways, virtualization modules and SDN modules. Virtualization modules calculate virtualization-related delays such as scaling delay or provisioning delay. First, simulation nodes are placed depending on the topology of user codes. Dynamic workloads (Simulation timely changes of workloads) of core NFs (MME, P/S-GW) are generated by using static workloads of parameters of user codes. VNF delays are calculated after configurating scaling thresholds and analyzing the topology, VNF policy. SDN modules also places simulation nodes first. They configure OpenFlow switches and a controller. After then they run OpenFlow application such as QoS bandwidth controller. The final simulation results come out by merging results of virtualization modules and SDN modules.

III. Conclusion

In this paper, we introduce 5G K-SimNet, which is developed based on ns-3 and has the features of dual radio protocol, traffic management on multi-connectivity, and SDN/NFV. Various performance metrics of 5GS, end-to-end performance, such as RTT, transport layer throughput and congestion window size, and performance of specific protocol, e.g., PDCP packet drop rate, RLC queue status, and PHY SINR, can be evaluated by using 5G K-SimNet.

References